Applying Aircraft Noise Reduction Technologies at its Source

Progress in Technological Development

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- Motivation & Fundamentals
- Aircraft Noise
- Operational Measurements
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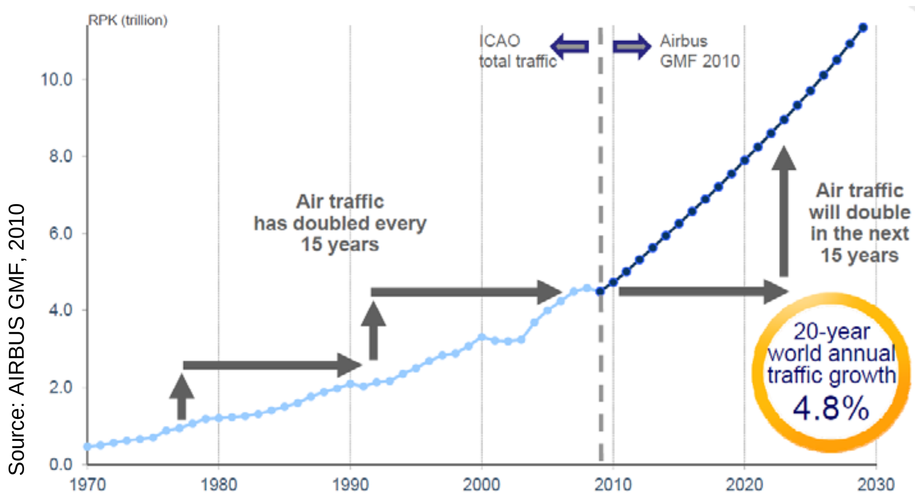
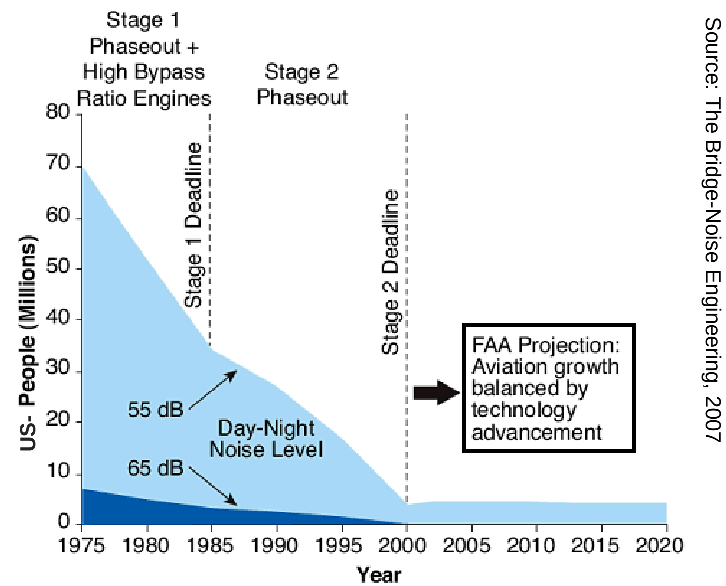
Motivation & Fundamentals

Motivation

- **Decoupling of noise impact from traffic growth**





- **The <u>balanced approach</u> must include**
  - **technological advances,**
  - **operational advances,**
  - **operating restrictions and**
  - **better land-use planning around airports**

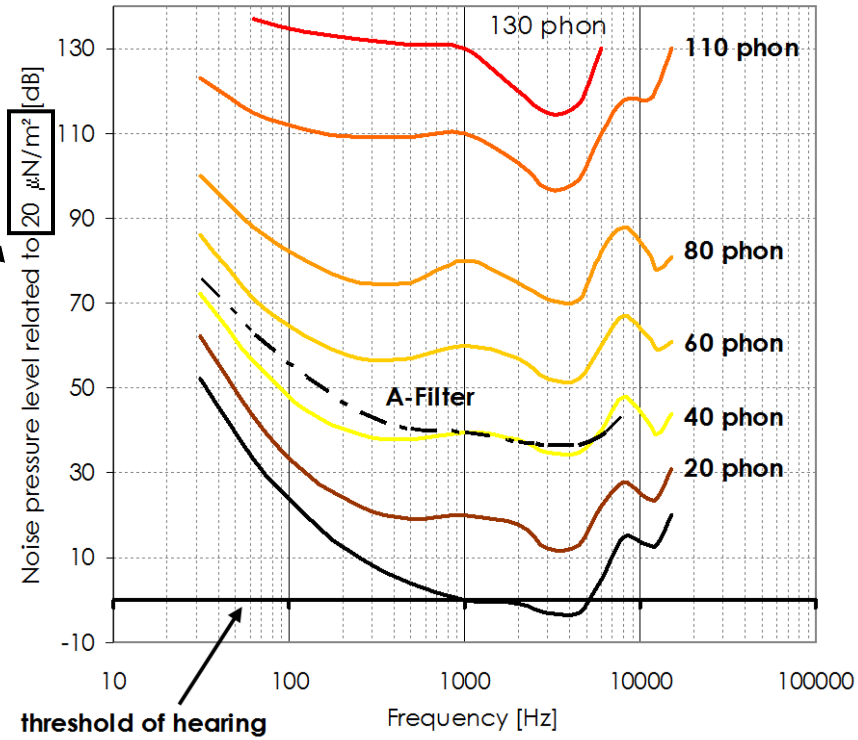
Fundamentals: Sound pressure level SPL or L

- Sound pressure or acoustic pressure is the local pressure deviation from the ambient (average, or equilibrium) atmospheric pressure caused by a sound wave

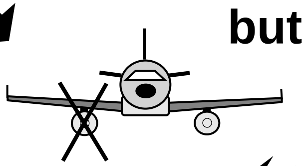
- The sound pressure level (SPL) or sound level **L** is a logarithmic measure of the effective sound pressure of a sound relative to a reference value.

$$L = 10 \cdot \lg \frac{p^2}{p_0^2} = 10 \cdot \lg \frac{I}{I_0} \quad \text{[dB]}$$

- The **reference value** is set at the typical threshold of hearing of an average human, with p_0 = 0.00002 Pa or I_0 = 10-12 W/m²



! **Halving of acoustic power (sound intensity) corresponds to a level change of -3dB only**

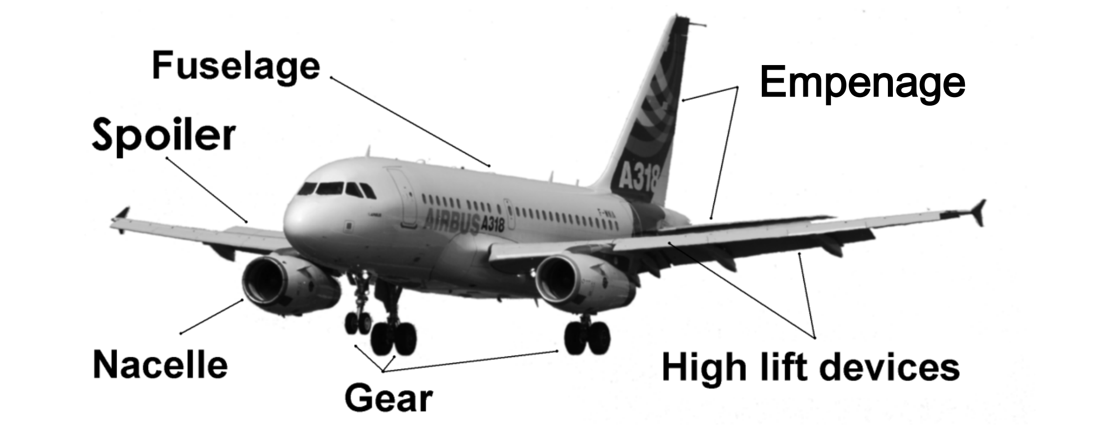


but: **10dB <u>decrease</u>** in sound level corresponds approximately to a **perceived halving** of loudness

„challenging"

Aircraft Noise

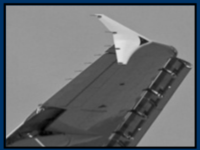
Aircraft Noise = Airframe Noise + Engine Noise

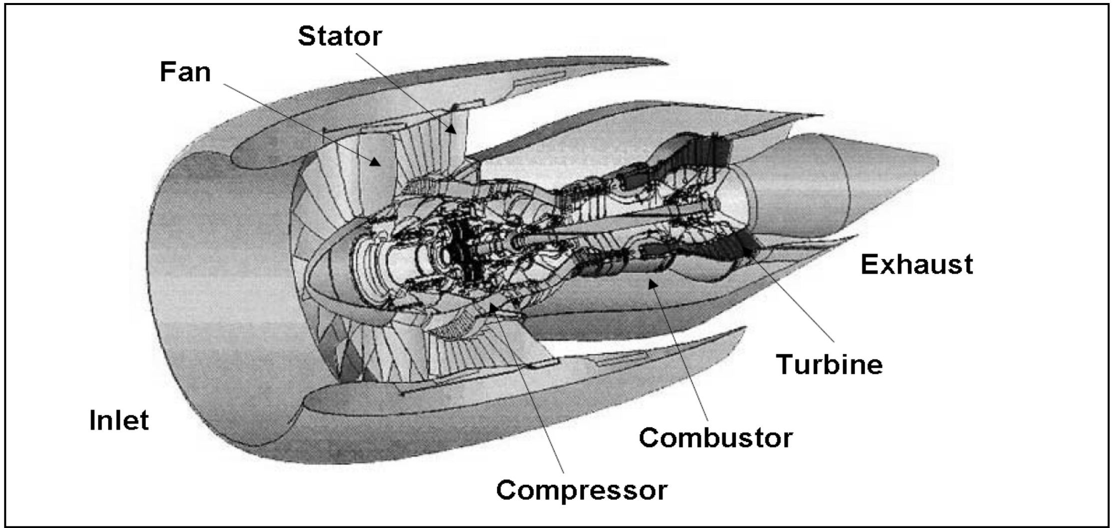


Airframe noise sources

Dominating sources:

- ***Gear***
- ***High lift devices***





Engine noise sources

Dominating sources:

- ***Fan / Compressor***
- ***Exhaust jet***

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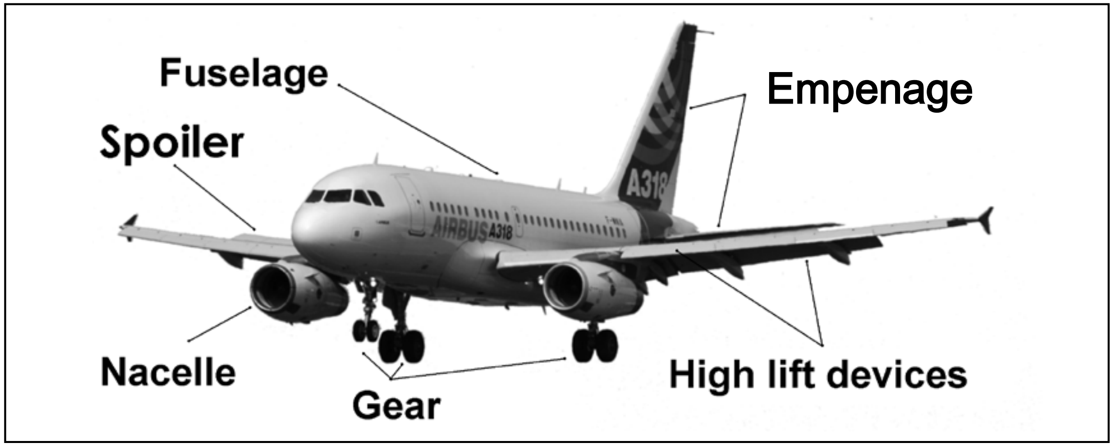

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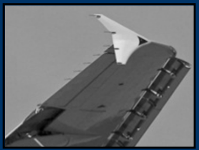
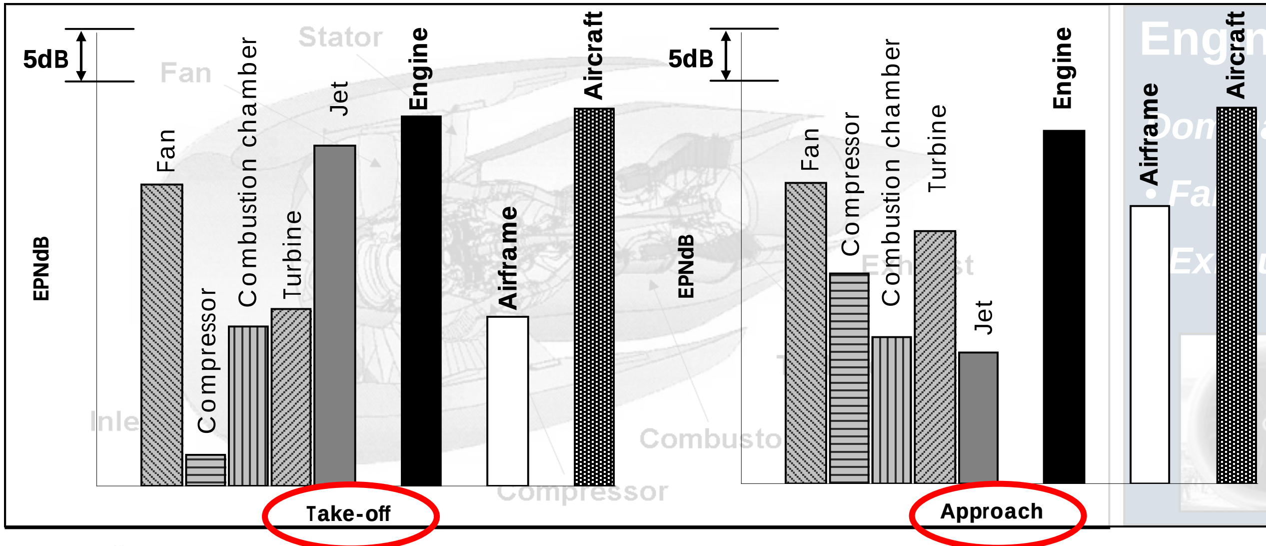
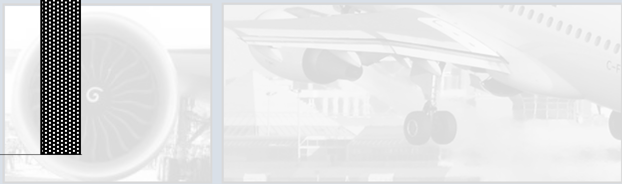




Engine noise sources

- On approach, the airframe makes as much noise as the engine.
- On take-off, the engine noise dominates



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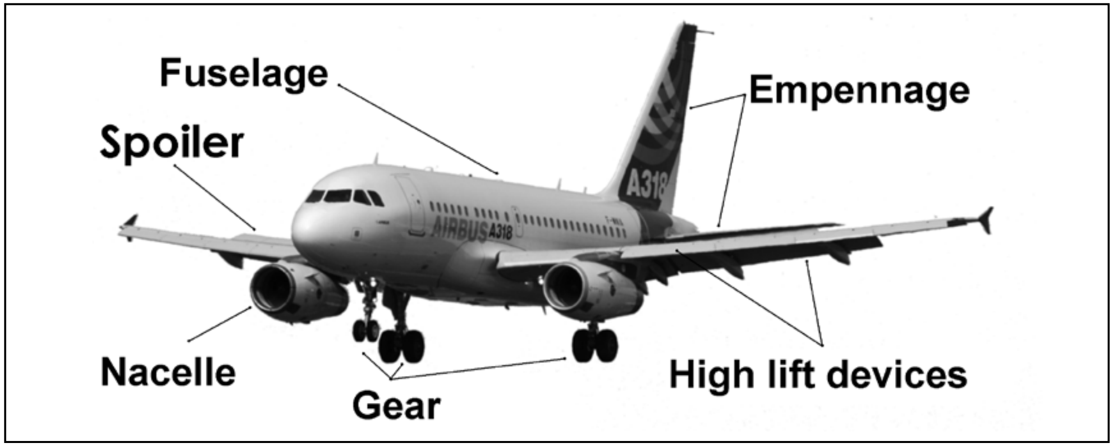

Airframe noise sources

Dominating sources:

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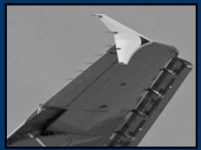
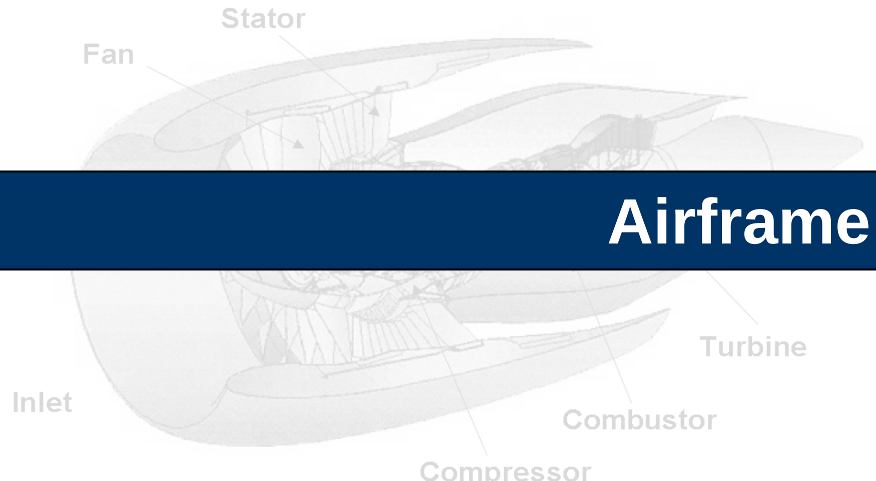




Engine noise sources

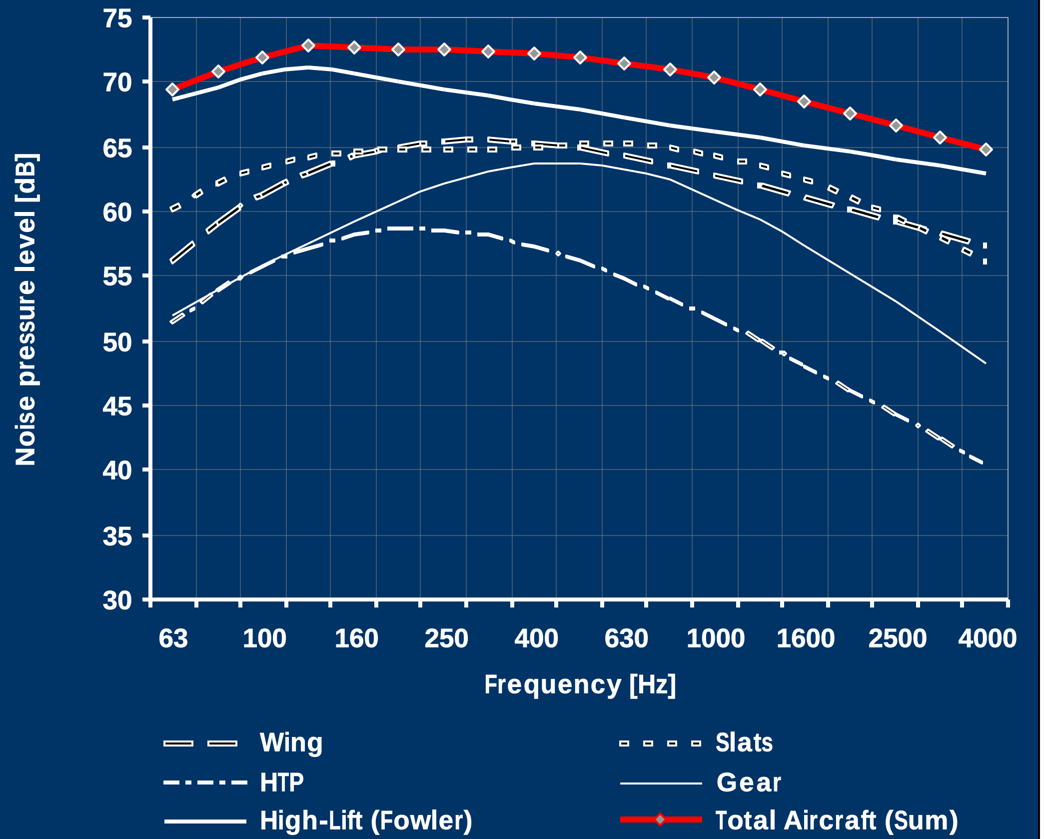
Dominating sources:

Airframe Noise

Airframe Noise

The airframe part with the highest noise level dominates the overall aircraft airframe noise (w/o engine).

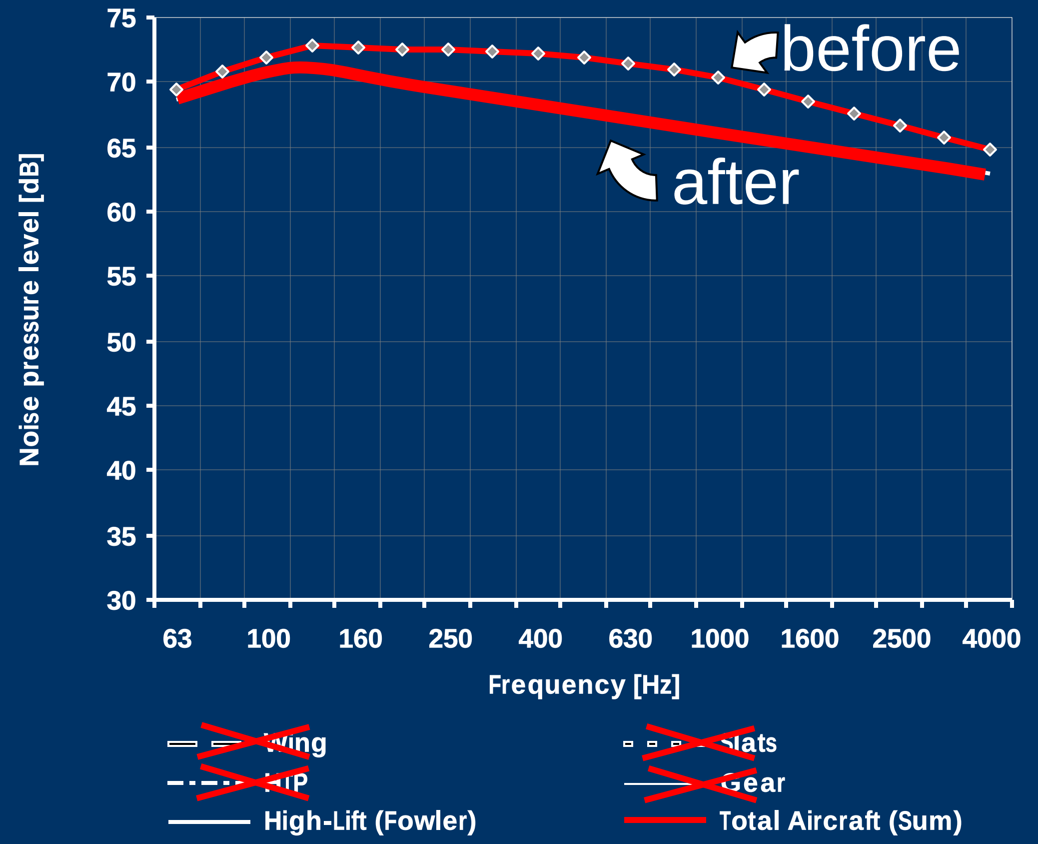
In the right diagram (example calculated) the high-lift devices are deflected and causes the highest noise pressure level over the frequency spectra.



Airframe Noise

Academic example:

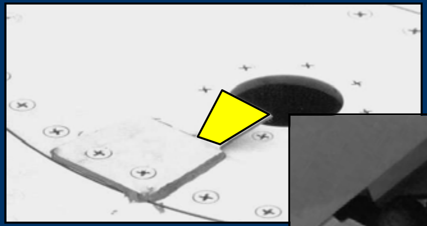
All airframe noise sources, except high-lift devices, are **switched off** (right picture). Nevertheless the overall airframe noise is not reduced significantly.



Consequence: The noise pressure level of all airframe parts must be reduced equally to reach significant overall airframe noise reductions!

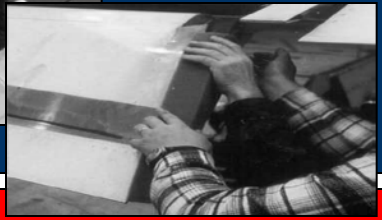
Identification of Noise Sources at Aircraft

- Transfer of wind tunnel based expertise into real flight situation
- Reduction of excess noise from „acoustically detrimental“ details
- Examples…

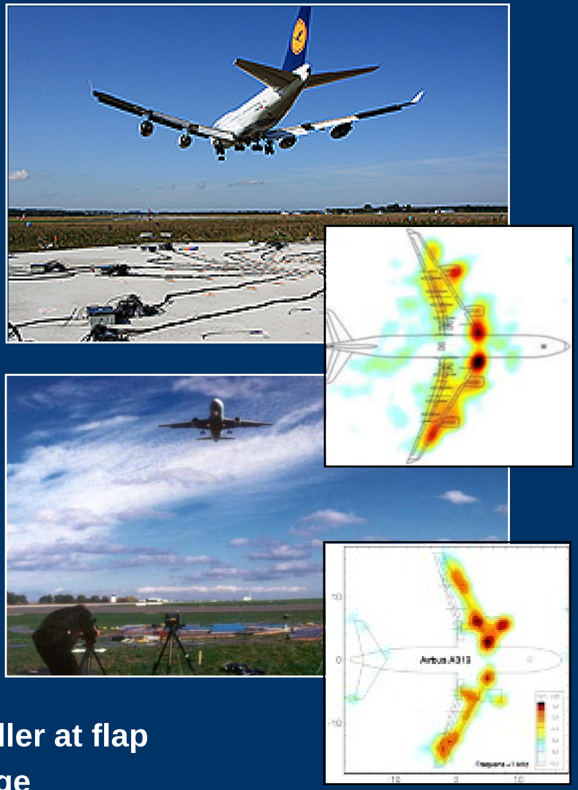


Vortex generators to eliminate hole tones

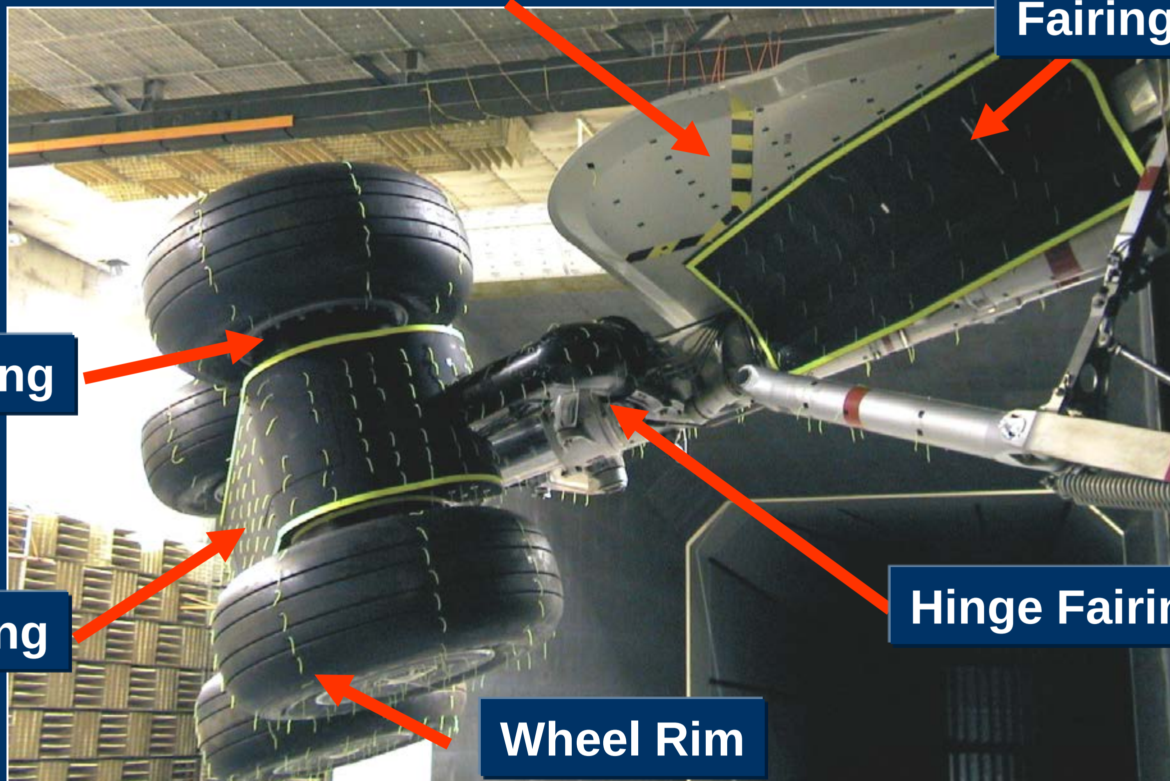
Sealing of slat track cutouts



Foam filler at flap side edge



Measures for Aircraft Noise Reductions



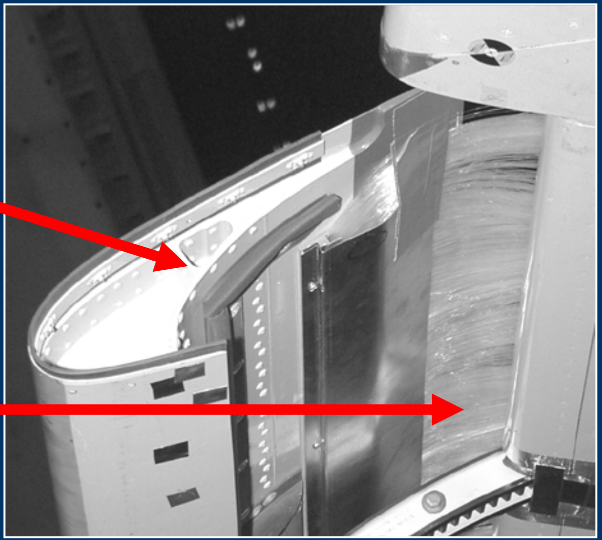
max. -5 dB through realistic partial fairing

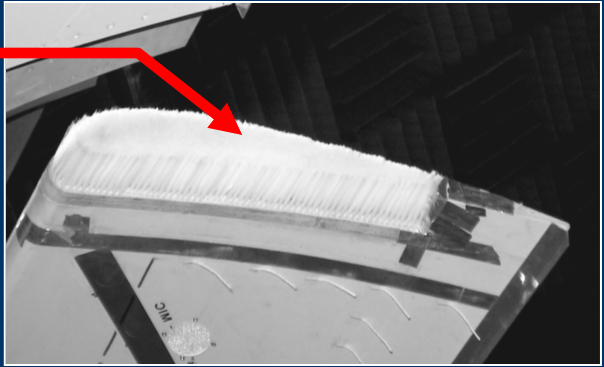
Measures for Aircraft Noise Reductions

-2 dB by fillets in cavities

-5 dB with slat trailing edge modifications

-5 dB by flap side edge modifications



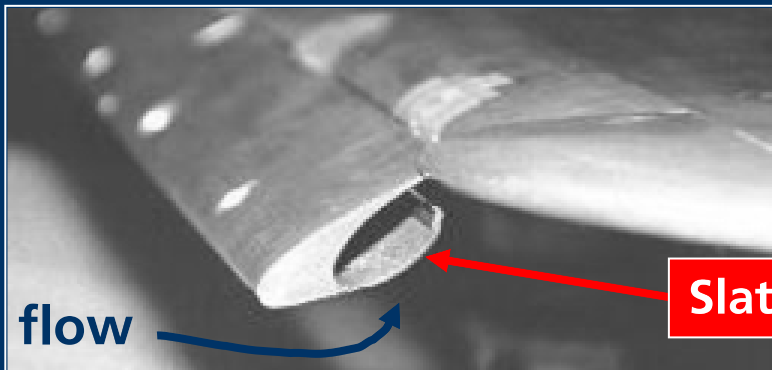


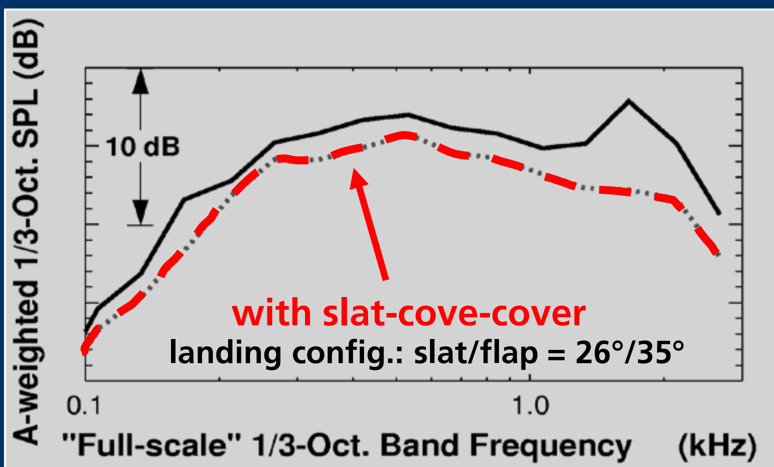
sound intensity ~ $p'^2 \sim v_\infty^5$

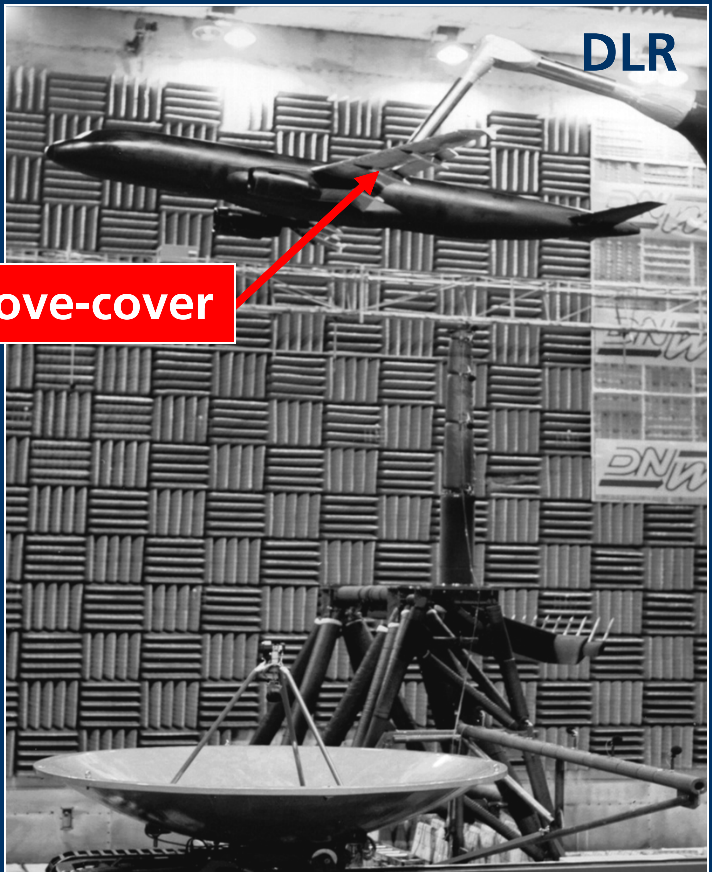
sound level scales with the fifth power of velocity

3 dB reduction ⇐ 13% decrease in speed

Measures for Aircraft Noise Reductions







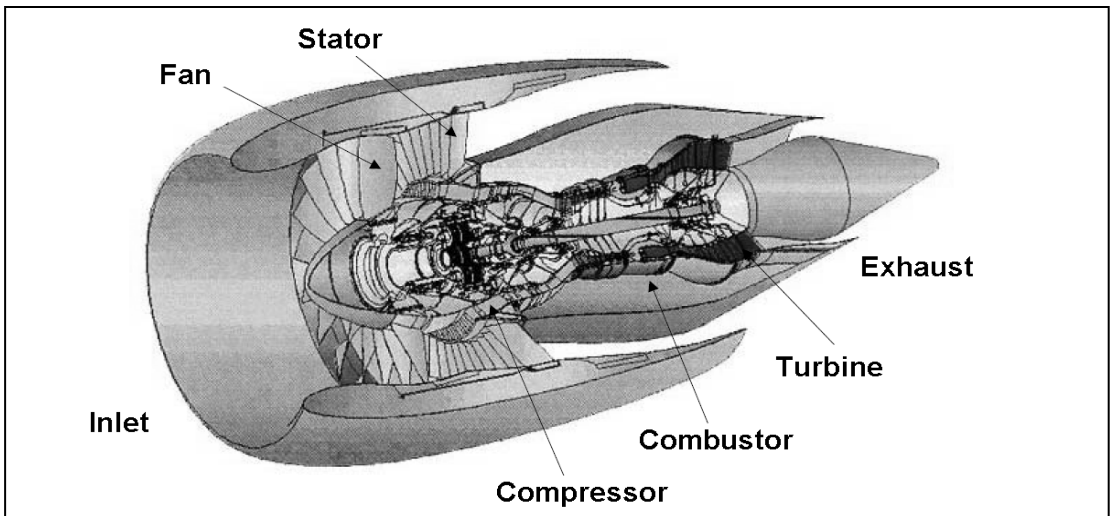
-3 dB far field noise reduction

Aircraft Noise = Airframe Noise + Engine Noise

Airframe noise sources

Dominating sources:

Engine Noise and Reduction



Engine noise sources

Dominating sources:

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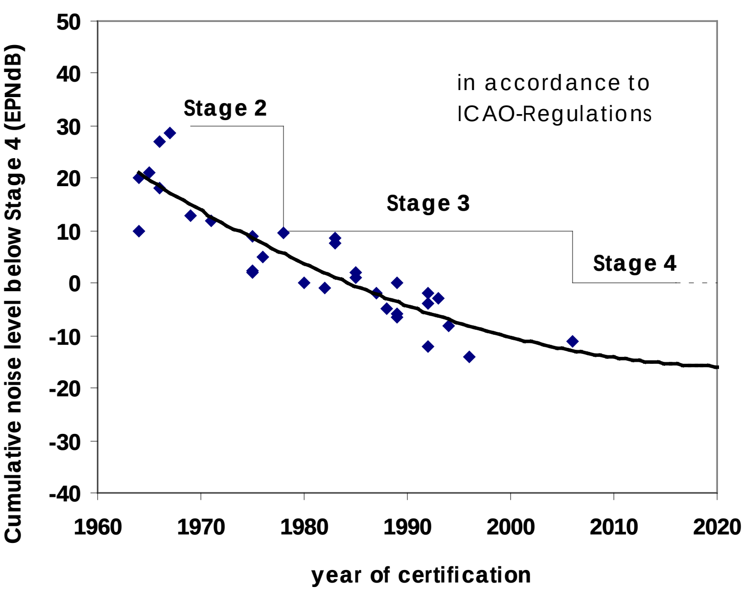
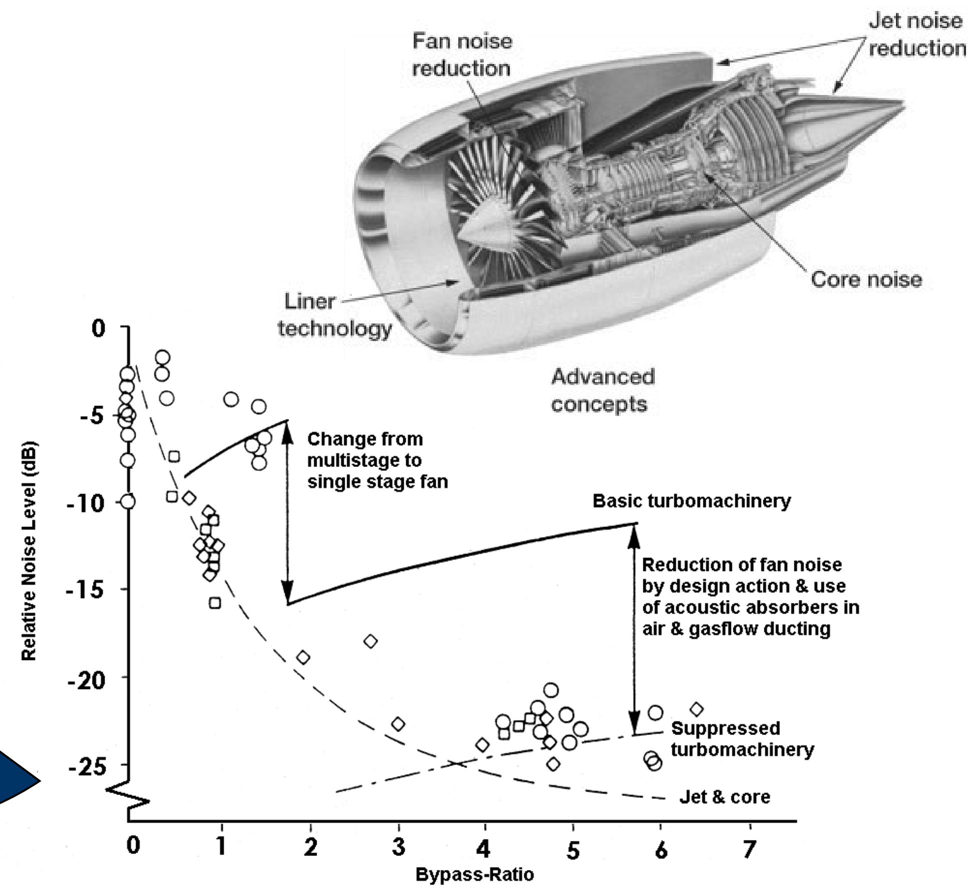
Engine Noise and Reduction

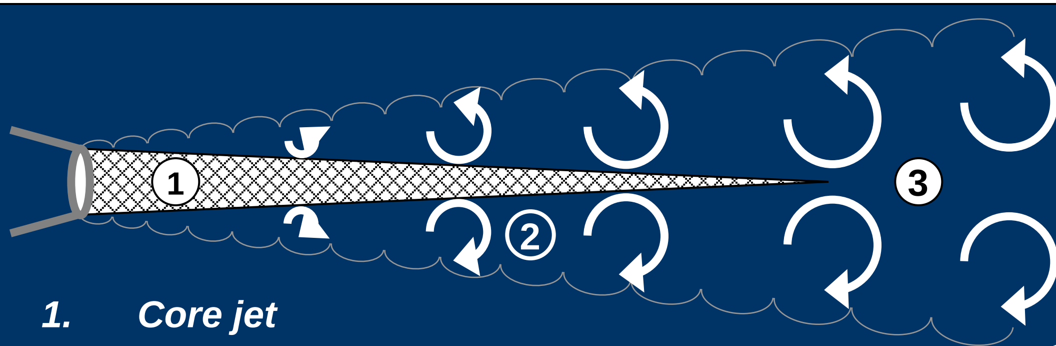




„big share“

past (low bypass) → current (high bypass)

Engine Noise and Reduction (jet noise)



1. *Core jet*
2. *Turbulent mixture zone*
3. *Fully developed turbulent jet*

Forced mixing of low and high speed jet:

ø jet velocity reduced!

$$L_{jet} \sim v^{8}_{jet}$$

Simple assumption:
Jet sound pressure level scales with the <u>eight power</u> of jet velocity

Halving velocity → -25dB

A320 (Test vehicle)

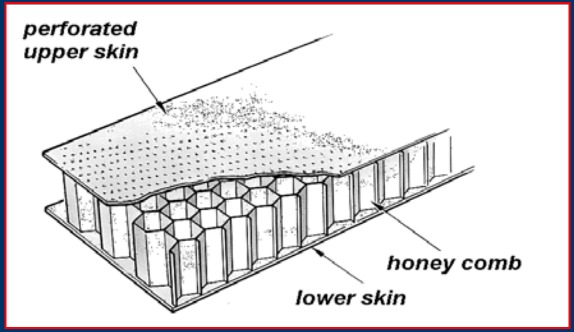
B787

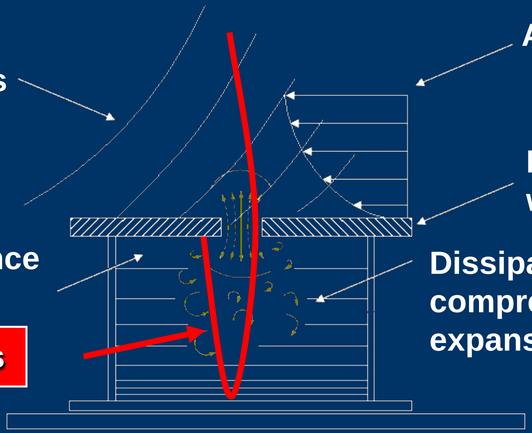
Gulfstream III

-1 to -4 dB far field noise reduction

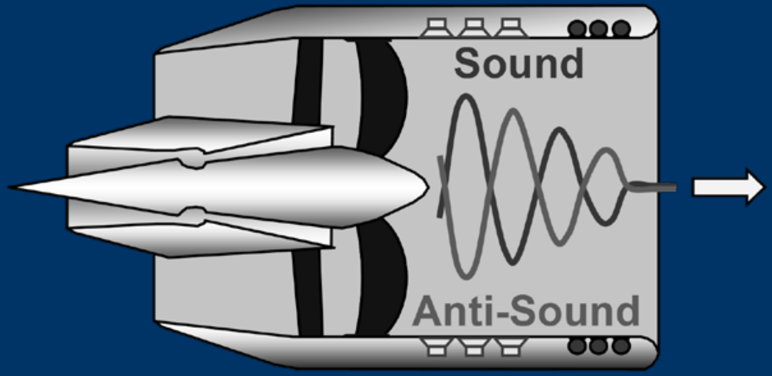
Engine Noise and Reduction (fan/compressor noise)

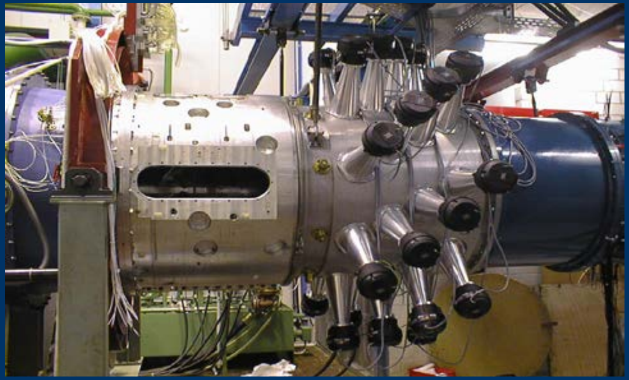
Passive Noise Control for Aero Engines (Liner)





Active Noise Control for Aero Engines

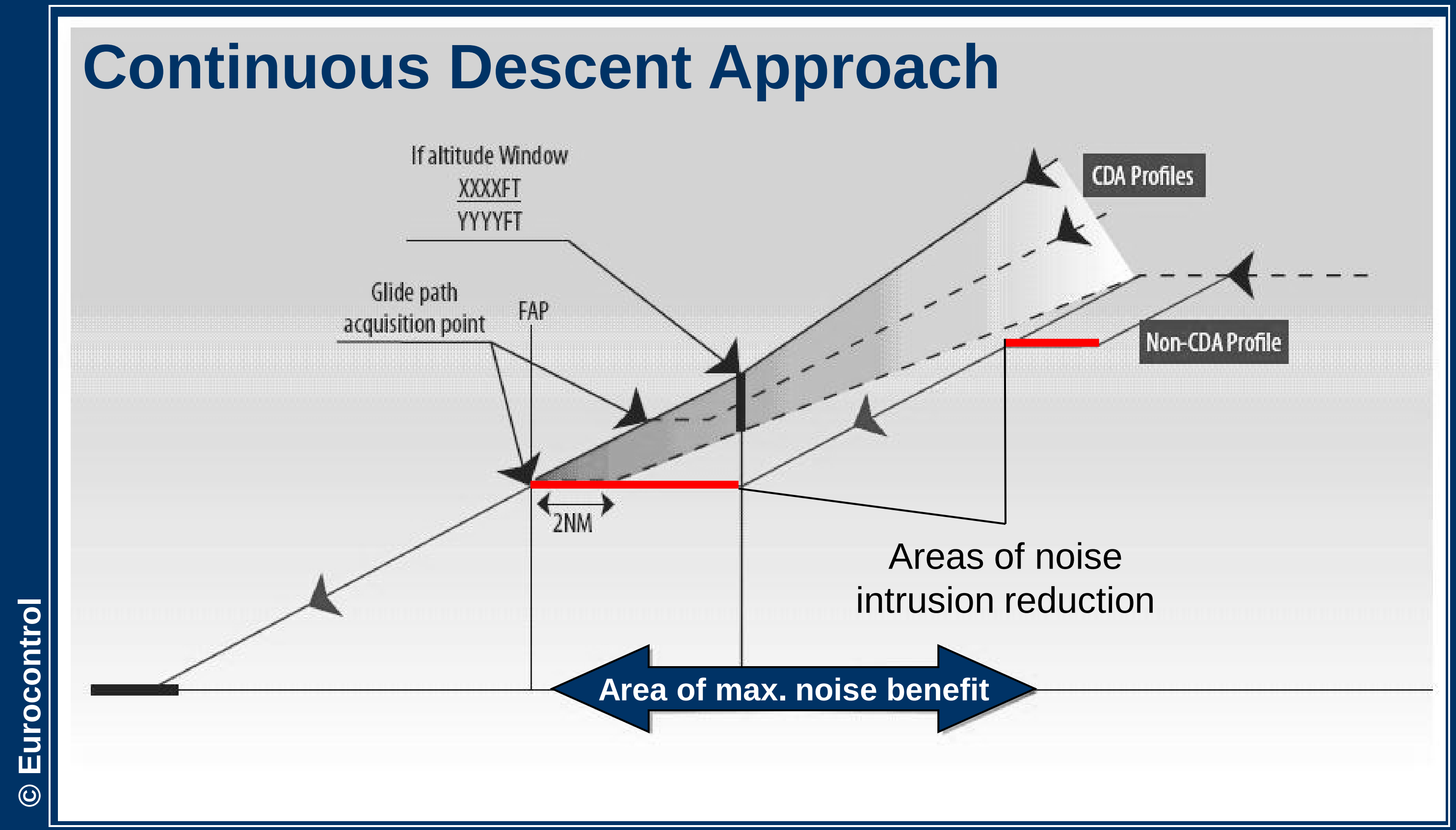




-1 to -4 dB far field noise reduction

Operational Measurements

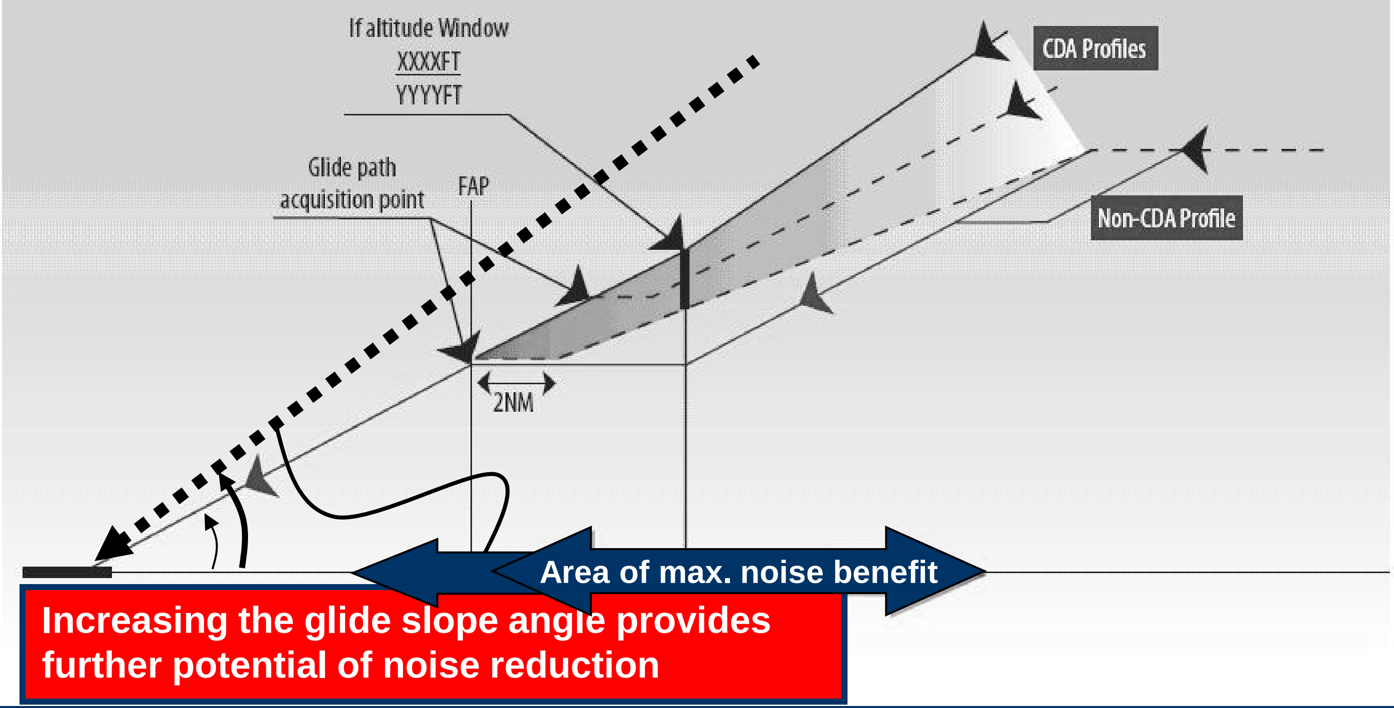
Operational measures for noise reduction



Reducing noise on the ground by around 1-5 dB per flight

Operational measures for noise reduction

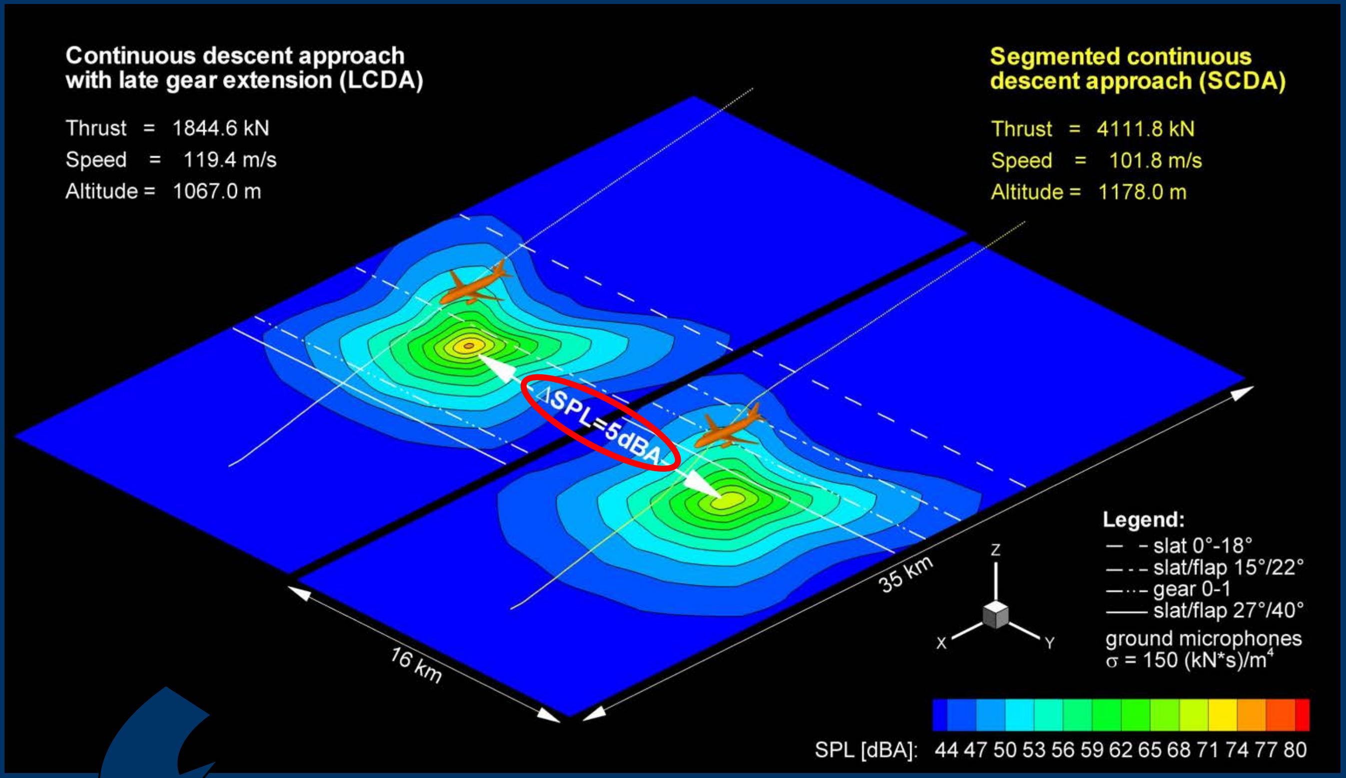
Continuous Descent Approach



© Eurocontrol (adapted)

Reducing noise on the ground by around 1-5 dB per flight

Operational measurements of noise reduction



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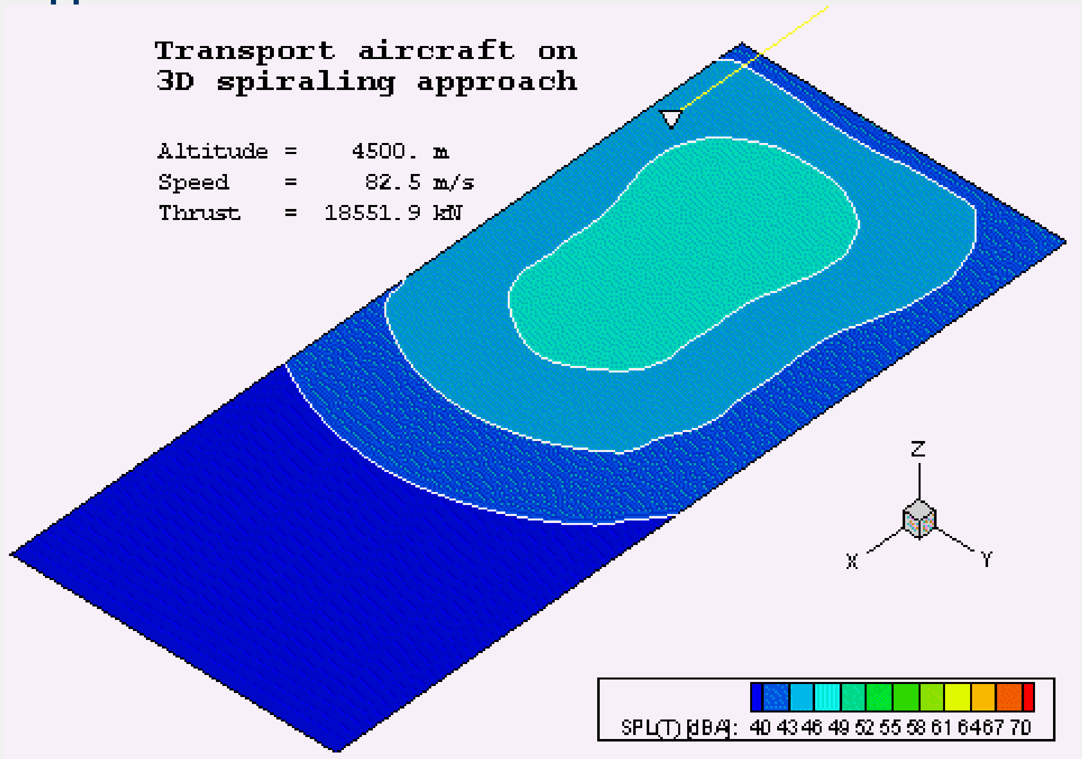
Level of noise reduction depends on CDA-profile

Operational measures for noise reduction

Unconventional Approaches



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Relocating approach in less noise sensitive areas

Operational measures for noise reduction

Other commonly applied noise management measures include:

- **avoiding fly-over sensitive sites such as hospitals, schools, hometowns**
- **using continuous descent approaches and noise abatement departures**
- **avoiding use of auxiliary power units by aircraft on-stand**
- **towing aircraft or electrically driven landing gear instead of using jet engines to taxi**
- **limiting the number of operations or the extent of a critical noise contour**

Future Aircraft Configurations

© Airbus

Future Aircraft Configurations examples

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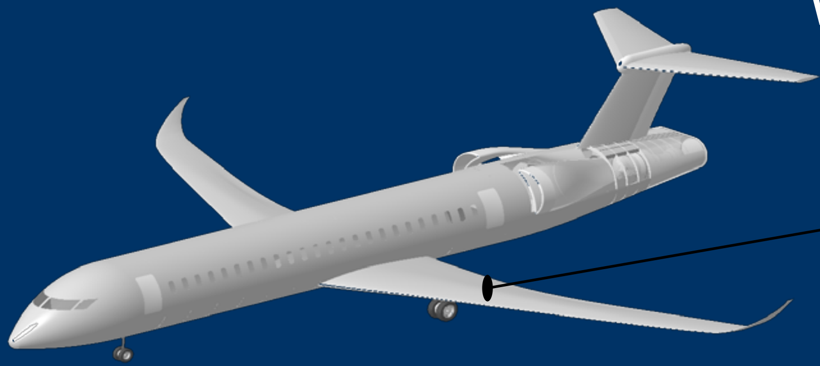
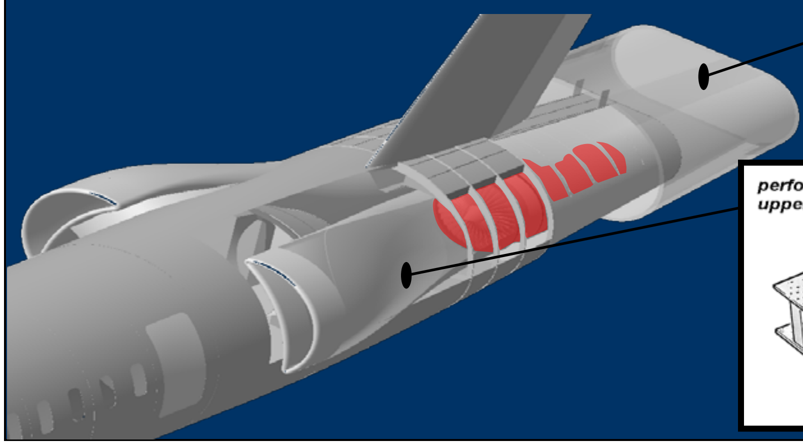
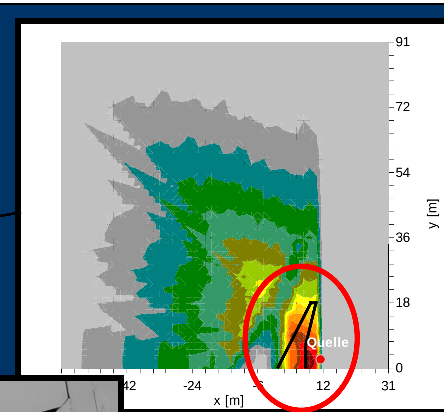
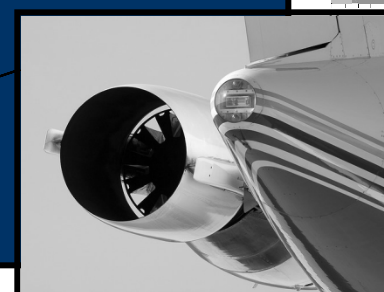
Future Aircraft Configurations (example)



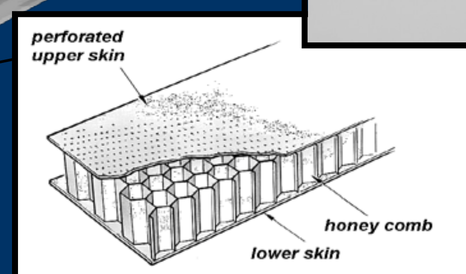


Wing shielding to reduce forward emitted noise



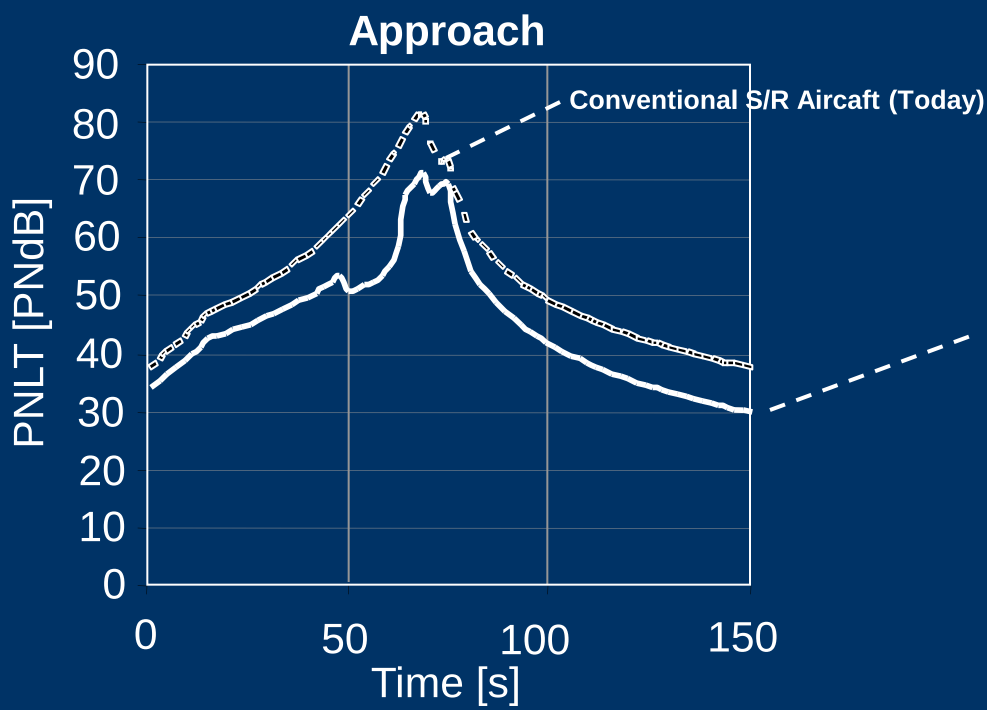


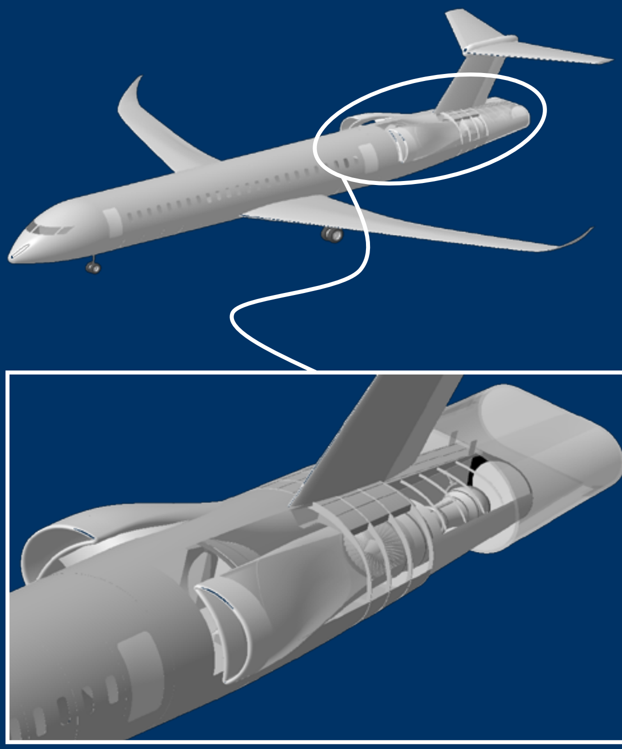
Ejector principle to control jet noise



Long intakes with liners to supress fan noise

Future Aircraft Configurations (example)

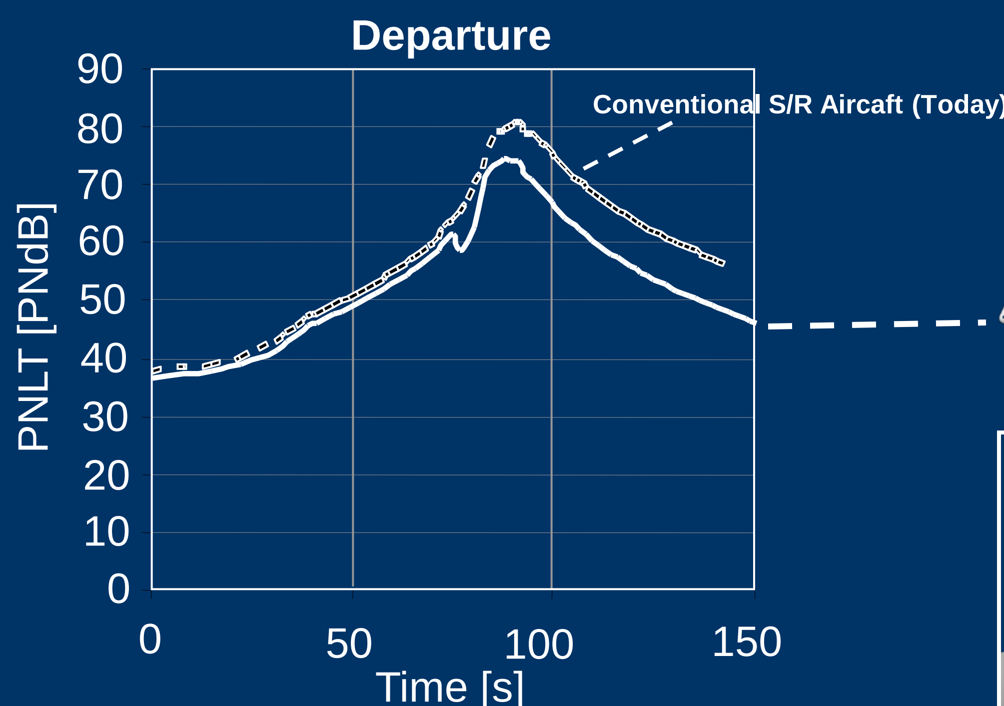


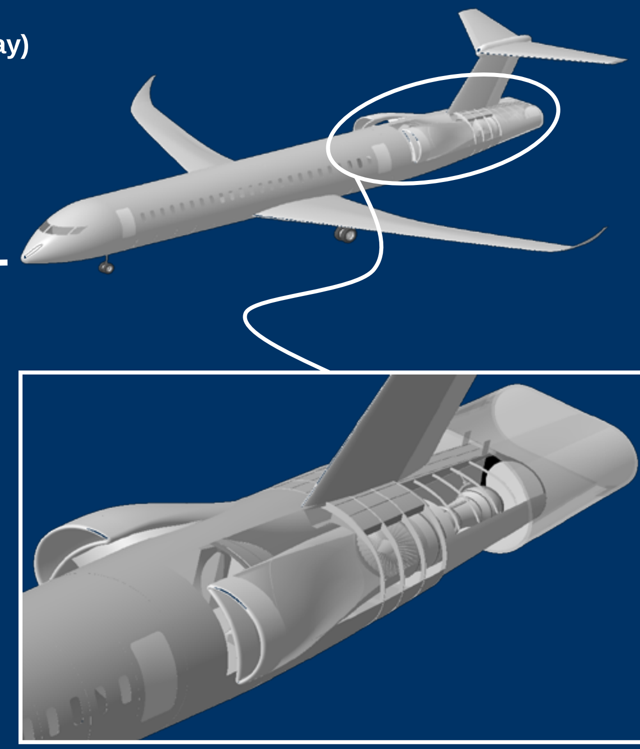


Approach = -8,7 EPNdB

Design advantage: Noticeable noise reduction (engine)

Future Aircraft Configurations (example)





Take-off = -6,6 EPNdB

Design disadvantage: Deteriorated fuel efficiency

Conclusion

Conclusion

- Noise impacts increase with growing air traffic
- Balanced approach: Decoupling of Noise impact from air traffic growth
- Technical and operational improvements for noise reductions have to be introduced equally to attain the highest potential of noise reduction
- The change in current aircraft design philosophies promises a high potential in future noise reductions